Canadian Fishing at the Grand Banks, Zebra Mussels, and Iron's Effect on Plankton

an example of plausible connections

By **Christopher YUKNA**

Abstract

The destruction of the fishing in the Grand Banks is one of the greatest ecological disasters of our time. Its collapse is the basis for countless articles and international fishing quotas. This paper develops an alternative explanation using the enormous information available via scientific search engines like Scirus, Google Scholar, as well as other sources like Google and Wikipedia. By examining many domains and disciplines and then choosing appropriate concepts and events to form new insights. This hypothesis involves the invasive species the Zebra Mussels and their possible impact on iron fertilization of the Grand Banks. Did Zebra Mussels remove the iron from the Great Lakes and Saint Laurence River watershed? Could the lack of iron really be prolonging the depletion of Grand Banks fisheries? Also presented a brief explantion for the rich sealife found in Truk Lagoon and around oil platforms.

Introduction

Justifying a second look can be explained by the continued effects of this event. The importance of this topic is reflected in the many websites that the decry the loss of culture, lifestyle, and fishing of the Grand Banks. Over Fishing has been blamed for the collapse of the Grand Banks marine ecosystem . The almost total disappearance of commercial fish species has affected both scientific perspectives and environmental regulations world wide. To lose such valuable economic assets like cod, flounder, Greenland halibut, and redfish has had deleterious effects on the fisheries and the people who relied on them for their living. By 1995 most of the fishing in the Grand Banks areas were either closed or restricted. There is slight hope for a comeback in the future as stocks show little evidence of recovery.

In addition, Greenpeace hosts one of the more famous sites: It can't go on forever. which extensively covers the topic of overfishing Their arguments seem solid and incontestable. Unprecedented factory scaled fishing fleets were literally vacuuming up fish in these historically abundant zones. The disregard for the long term and focus on short term gain is deplorable. This is not in question. Yet, from the ecological management perspective there is evidence that we do not fully understand the biological or system interactions that occur in the ocean. As we have become guardians or gardeners of our blue planet, it is crucial that we identify and become sensitive to the complex connections that interlace our Earth .

Where is the Mystery?

In order to progress in science, you need to have a question, puzzle or mystery. Without questions there is no search for answers. Let's begin. For centuries, the Grand Banks have been one of the richest fishing zones in the world. As early as the 15th century, Basque fishermen were reported to have fished there. From the 17th century onwards boats from England, France, Portugal Spain, came to the part of the New World to fish. In 1602, Bartholomew Gosnold named Cape Cod ,Massachusetts (in George's Bank see illustration right.) saying that one could walk on the backs of the codfish to shore. Yet all of that abundance changed when the fishing stocks collapsed in the late eighties and early nineties. So with a fishing moratorium in place for the last 11 years...

Courtesy of Fisheries and Oceans Canada

"The early 1990's saw a historic collapse of Canada's Atlantic cod fisheries. At the time, most people looked forward to an early recovery. Instead, most fisheries have stayed closed. Cod populations remain depleted, and the reasons remain disputed." What's Holding Back the Cod Recovery?

As you can see from the above quote, why would an area historically bountiful in fish cease to be productive even after years of no harvesting? What made the Grand Banks so bountiful in the first place? Traditionally, the richness

has been explained by the intersection of two powerful ocean currents, the cold Labrador Current coming down from the North and the warm Gulf Stream from the South. They even affect the climate, producing many foggy days. Both currents bring nutrients to the Grand Banks. This explains the abundance or at least it should. But what if there were a missing ingredient? One that somehow disappeared during the late 80s and early 90s? This fertile area seems to have permanently lost its fecundity. Are the Grand Banks missing part of their nutritive base?

Where Did the Food Go?

There are many reports of codfish starving in the Grand Banks. Why no food? Ostensibly, the plankton has gone or been severely altered. What would cause this plankton paradox? No one was fishing plankton. Think about this for a moment. Plankton are often composed of plants (Phytoplankton and some forms of photosynthesizing bacterioplankton.) How would removing animals (codfish, halibut,etc) affect a forest (the plankton)? When the American Bison or Buffalo was almost driven to extinction the grass on the prairie did not disappear. A better American analogy would be the removal of wolves that limit grazing deers. Even, in this case, forests have not reduced and the coyote is rapidly filling the wolf's ecological niche. What is different about the ocean? Plankton should not be under severe threat. Furthermore, the codfish is NOT extinct. Cod reach maturity at six years, producing clouds of eggs at a time. So why no regeneration after more than two generations? There are many theories some expressed and some undisclosed as to why there is no recovery.

While of not of primary importance to this article, many interest groups blame the rising Grey seal population. These interest groups are demanding a seal cull. At first glance, this would seem logical: seals eat fish so less seals equals more fish. However, seals existed alongside this great fishing zone for eons. There seems no acceptable reason that their influence would suddenly become detrimental to fishing. A cull is short sighted. One of the reasons that I began to investigate this event was in the hope of protecting these seals.

What do scientists think Of the Grand Banks collapse? It is very hard to obtain a holistic view across an entire scientific field. Perhaps examining one paper written by nineteen diverse specialists could help. Here is a quotation from their abstract:

"*Ecological extinction caused by overfishing precedes all other pervasive human disturbance to coastal ecosystems, including pollution, degradation of water quality, and anthropogenic climate change. Historical abundances of large consumer species were fantastically large in comparison with recent observations. Paleoecological, archaeological, and historical data show that time lags of decades to centuries occurred between the onset of overfishing and consequent changes in ecological communities."*

from the paper:

Historical Overfishing and the Recent Collapse of Coastal Ecosystems

As mentioned there are nineteen authors associated with this quote. They are from prestigious institutions: Scripps in California to Center for Coral Reef Biodiversity in Australia. Obviously, they feel that this is more important than Global Warming. So crucial and large that they all need to collaborate on this topic. They may be right or perhaps they need to be numerous to suggest that time lags between cause and effect can span decades or even centuries. This does strain credibility. These people are very intelligent. If the solution were in their fields they would have found it. Obviously, something essential is lacking . If the answer or answers lie outside their disciplines or in outside the Grand Banks then it is understandable that they were unable to make the connections. Since the principle of Man's overfishing has already been established, there was no need to look any farther for a root cause. Should we question this base? The ecological disaster of the Grand Banks is still affecting the lives of both people and animals. There were countless fishing villages, fishermen, and the resultant industries dependent on this lost fishing zone. Any future regulations or quotas have to be based on the horrific experience of the Grand Banks. To correctly understand what really happened is of paramount importance .

While being a major factor, perceptibly, overfishing may not be the principal cause. Indeed, at first glance, it does seem reasonable that the disruptive nature of modern fishing methods could severely damage an entire ecosystem. Could this even therefore rendering it far less productive permanently? But the mechanism for this irreparable damage has not been sufficiently explained. What if overfishing was only one aspect? Once more, what if there was another theorem that might better explain why this cultural, economic, and ecological disaster is enduring? That is what this paper seeks to explore. How can an outsider, landlocked in central France, hope to accomplish this task? By applying an old idea, that Science, even in the 21st century is not reserved only for specialists. By looking through the eyes of Google et al , Wikipedia, etc. everyone can contribute to solving life's mysteries. Everyone can be a sort of Natural Philosopher. The basic presumption is that by scanning science as a whole one can copy and paste a series of ideas, quotes, and articles that together form something entirely original. If you continue reading,

then you are about to take a whirlwind tour of science and our world.

Next Stop the Truk Atoll

Some questioning thoughts on ocean fertility began here. What is the story?

During World War II the Truk Lagoon (Chuuk) served as an advance base for the Japanese Fleet. In 1944 at least 35 Japanese warships were sunk in the Lagoon. After the war and to everyone's surprise, this vast graveyard of ships turned into an undersea paradise. Certainly, a junkyard of warships on land would be considered an industrial eyesore or even toxic waste site. How could they turn into one of the most beautiful and fertile areas in the Pacific? Today, this atoll is visited by people from Russia to Peru. Truk or Chuuck lagoon has even been named a National Heritage Site

Before this momentous event the lagoon had a unremarkable sandy bottom. While not sterile, the lagoon was not noted for its fecundity nor corals. Since the wreckage, there have been numerous studies of this lagoon some observing increased rates of growth for the Truk sponges.

Moreover, the film and photographs taken here by Jacques Cousteau in 1971 astounded the world.

The amount of fish, corals, and other sea creatures that inhabited these wrecks was more than a bit puzzling. This odd "effect" was explained away at the time, by stating that plants needed something solid to anchor to and animals need something to navigate from. Or maybe they came to eat the plants. So, this was why so much life sprung up in the lagoon.

Another unexpected place to find fish has been on or near drilling platforms much to the chagrin of many ecologists. Evidently the steel pillars of these rigs make an excellent habitat for sea life. (Please do not think that I am belittling the perils of offshore drilling. There are always grave risks from spills, toxic pollution, etc.) There is even evidence that oil platforms can create coral reefs)

This "oil rig fertility" is little understood.

"*Despite the popularity and effectiveness of artificial reefs and more than 50 years of study, scientists still have not completely explained how artificial reefs work. The obvious answer is that artificial reefs provide hard substrate for sessile benthic invertebrates and various species of algae plants that normally do not settle on shifting sand substrate. Small fishes come to feed on these organisms and larger fishes are drawn to feed on the smaller ones. Thus, artificial reefs set up a food chain. The problem with this explanation is that science has continuously failed to prove the food chain hypothesis.*" from Reef Results by Stephen Szedlmayer

Why Are There No Fish Far From Shore?

All of the great fishing spots are at or fairly near land. Actually the Grand Banks are almost an exception in that they extend so far out to sea. So why no fish in the majority of our oceans? This wonderful question was asked John Martin and he set out to discover why. He believed that plankton, like land based life, needed trace metals like iron or zinc to live. He also ran into a problem: contamination. Earlier studies were contaminated by the equipment used. Simple items skewed the results. An iron hull of a ship can raise iron water levels by hundreds of times. Copper & glass tubing introduce their own metal traces to samples. The solution was to use plastic.

"When the researchers at Moss Landing ran tests for trace metals in the newly renovated lab, they found that metal concentrations in the ocean were orders of magnitude lower than previously thought. Iron concentrations alone were thousands of times less than any measurement taken in the past."

Earth Observatory Giants

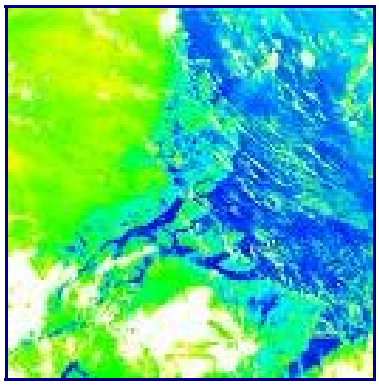
John Martin and his colleagues at Moss Landing Marine Laboratories obtained samples of water near land masses and then farther away. They noted one significant difference: that mid ocean water was very poor in iron. The farther water got from the continents the less iron found. The idea was that the sand and dust coming off a continent fertilized the water creating plankton blooms off shore. These would then be eaten by small crustaceans and small fish, then larger fish, in effect the food chain.

When he announced to the world that iron could fertilize the South Pacific barren zone or other desolate areas of our oceans John Martin was ridiculed. Here was a theory with teeth, testable, yet his critics ridiculed him, calling his ideas the Geritol solution. After his death in 1993 some of his colleagues, at the Moss Landing Marine Laboratories, tested this theory. They pumped soluble iron behind their boat, the Columbus Iselinin, in a desolate

zone near the Galapagos Islands. The next day a green line of algae several kilometers long appeared behind their vessel. John Martin's theory was vindicated. Controversy has since rose as how to use the amazing knowledge of "Iron Fertilization". But, this does not change the fact that plankton fertilization by trace elements is a proven scientific effect. Iron is a very common element on our planet, the 4th most abundant element in the crust. Certainly all animals and plants have need of this micro nutrient. Iron deficiency affects billions of people on our planet. They live on land close to sources of iron. As iron is very rare at sea, sea life is therefore particularly dependent on it. Could iron be the missing ingredient? Evidently, iron fertilization (and perhaps copper, zinc,etc) explains why Truk Lagoon and oil rigs are so fertile. (Oil platforms do NOT magically create fishing grounds as Oil companies like to suggest. Any metallic structure will do.) Are the Labrador and Gulf currents relatively poor in iron? Do they require an iron (or maybe zinc/copper) supplement? How could this be connected? After all, Canada did not move away. North America was not displaced. Did the wind patterns change? There are quite a few pieces of the puzzle missing.

Off to the Amazon

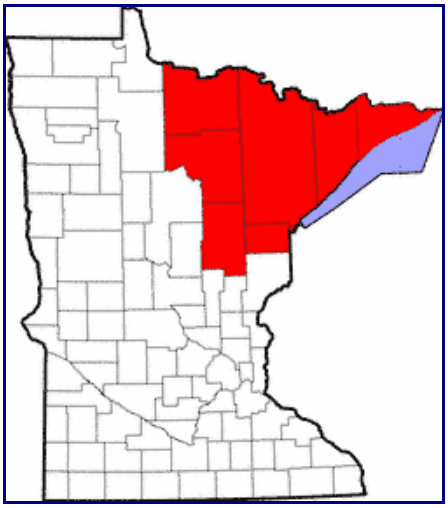
First, let's pause and take a look at river/ocean interfaces. After all, rivers, streams and underground flows might also transport iron. It has been suggested that one of the major sources of iron in the oceans is from rivers How far out could a river deposit its iron? The mightiest river on our planet the Amazon empties into the South Atlantic. Millions of tons of fresh water meet the waters of the South Atlantic at the mouth of this phenomenal river. Something like 20 percent of all the fresh water received by the oceans comes from the Amazon. Sometimes, even out of sight of land the water from the Amazon is potable (drinkable). Moreover brackish Amazonian water is known to exist hundreds of miles out into the Atlantic . Satellite image often shows algae plumes and Amazon sediment far out into the South Atlantic sometimes almost touching the coast of Africa! The Amazon can be detected as far away as Puerto Rico. So river water can cover immense areas in oceans and create algae plumes far away from their deltas..All of this because fresh and salt water do not mix very well. The lower density and warmth of fresh or brackish water makes it buoyant, spreading



Mouth of the Amazon
Courtesy of The ATSR Project

out over a large area. Is the Amazon overly rich in iron? It is hard to tell, but its basin has not experienced an ice age recently. Apparently the erosion of bed rock is a major source of iron and other minerals on this planet. More of this type of rock is exposed after an ice age. Another important mineral source is volcanic rock. Streams in the Andes, which are the source of Amazon, would erode both igneous and volcanic rock and thus should contain quite a bit of minerals. However, the vast numbers of plants and animals in the Amazon's waterways might tend to filter this vital element. There are studies of iron's important role on this marine/Amazonian ecosystem so perhaps a closer look might be interesting (click here). However, the Amazon doesn't seem to be overly iron abundant. There is not a historically famous fishing zone of the caliber of the Grand Banks associated with the Amazon . Given that a river could spread a huge layer of iron rich fresh or brackish water over the ocean., apparently, an exceptional amount of iron (and maybe zinc' etc) is needed. Where would we find this ultra rich mineral source ?

The Great Lakes and Minerals



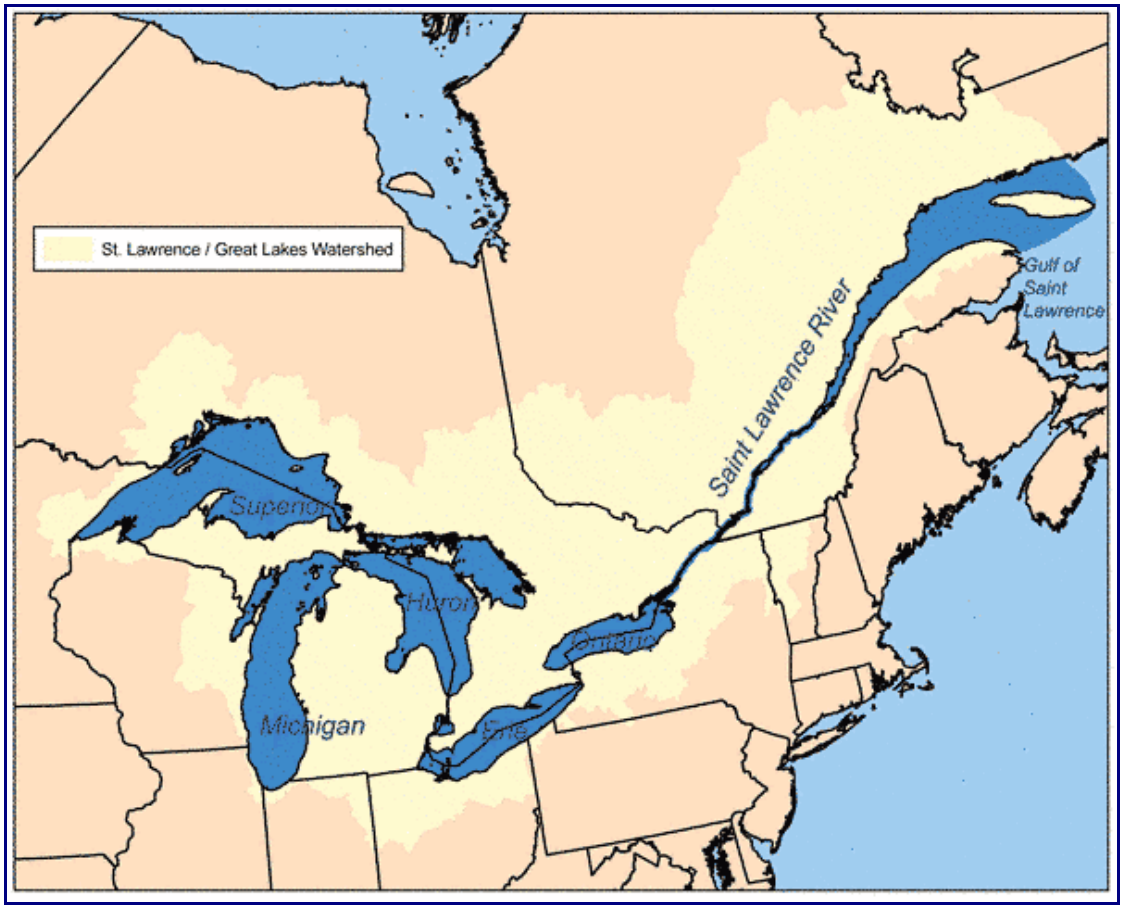
Historically the Great Lakes have been known for the iron ore trade. **Iron ranges around Lake Superior** have been the principal source of ore for North America for more than a century. It is not unreasonable to assume that their waters are rich in iron or at least they were. For example, the Iron Range of Minnesota. is located between Lake Michigan and Superior. Part of it is even underwater. According to Wikipedia the world's biggest open pit iron ore mine is to be found there as well in the Mesabi Iron Range : Hull-Rust-Mahoning Open Pit Iron Mine in Hibbing Minnesota. Also in Wikipedia,an article on Iron ore mentions: "Modern mines, in Minnesota and Michigan in the U.S., and Eastern Canada mine taconite.(a form of iron ore)" So it would seem that these areas in the US and Canada have ample iron. So, we have a possible exceptionally rich source of water soluble iron in and around the Great Lakes. By the way, iron ranges in general are thought to be biological in origin.

They were formed when the iron released from the continents by erosion, precipitated because the accumulation of oxygen in the atmosphere produced by marine algae. The availability of dissolved Fe decreased enormously when oxygen increased in the atmosphere and ocean , thus forming these deposits. It is theorized that marine life was heavily dependent on this iron and had to adapt to the significant change brought about by cyanobacteria. I mention this to highlight the fact that biological agents can alter the climate and the environment on a global scale. This will be important later on.

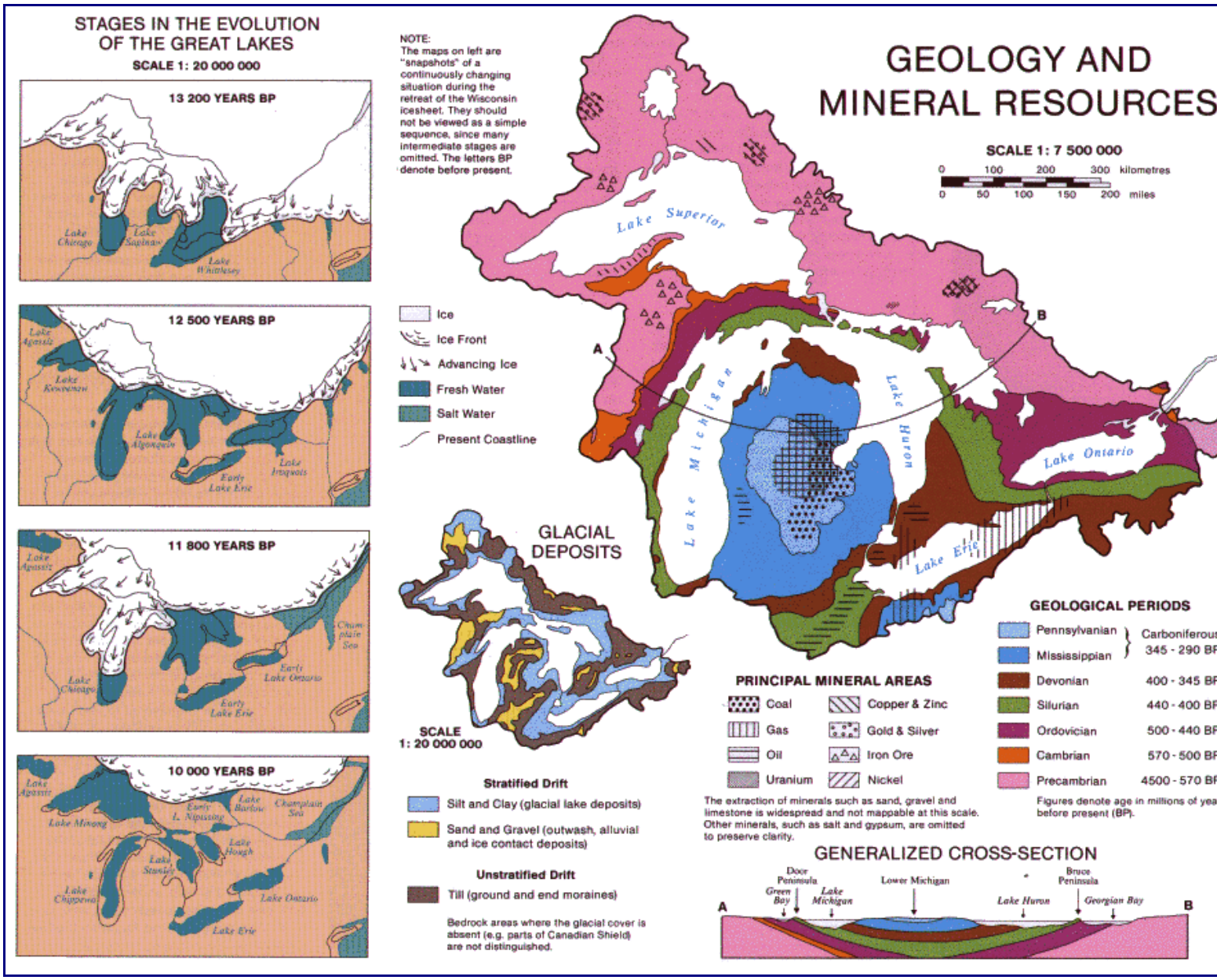
Back to our pursuit of the brainteaser. What about the river? Is there a river system like the Amazon involved in all this? If you remember your geography, the Great Lakes empty into the Saint Laurence.

If you look on the right at this wonderful map of our planet's largest freshwater aquifer or watershed. As you can see from this map, the watershed drains through an extensive area. Even if this were not a zone known to be rich in minerals (it is), the amount of iron strained through sediment would be considerable. For you see: Iron (Fe) is much more soluble under anoxic conditions. The amount of iron in the sea is very limited by the fact that this element precipitates out of solution in oxygenated water. Underground flows often lack an appreciable amount of oxygen . This is an area rich in minerals and working mines.

By the way, any form of mining can produce a sort of "natural" iron pollution outside the mine in the surroundings..



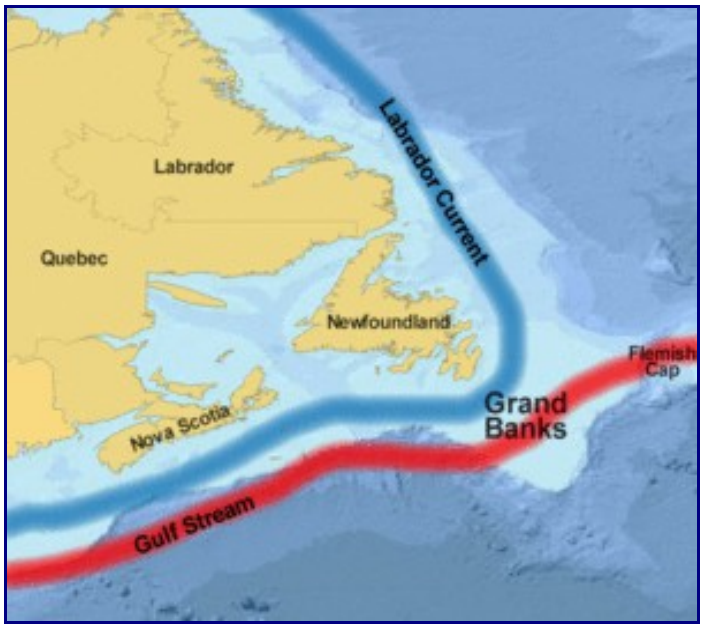
"Pyrite exposed to the environment during mining and excavation reacts with oxygen and water to form sulfuric acid, resulting in acid mine drainage. This results from the action of Thiobacillus bacteria,, which generate their energy by using oxygen to oxidize ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}). The ferric iron in turn reacts with pyrite to
produce ferrous iron and sulfuric acid. The ferrous iron is then available for oxidation by the bacteria; this cycle can continue until the pyrite is exhausted. " from Wikipedia
This process often deposits red iron oxide in the rivers and streams near the mines. Even if there is just a mineral deposit, acid rain can be responsible for producing water soluble iron as well. Therefore it seems likely that the waters of the Great Lakes might be rich in iron if only from underground sources.
Don't forget, the Great Lake region is incredibly rich in mineral content. It has gone through a recent ice age as demonstrated by the image below: As you may note from the illustration, this region is renowned for zinc and copper, which are also trace elements needed for life. In addition, The pink areas on the map denote the Precambrian, which is associated with banded iron formations and their successor the red beds of sandstones and siltstones with red iron oxide cement. Hence, phenomenal iron sources abound in this region



As aforementioned there is also the territory along the Saint Laurent and the Canadian Eastern seaboard that would affect in some
manner the metallic content of fresh water entering the Grand Banks. A few Internet searches will find quotes like the following:
"In Canada, Newfoundland and Labrador is the largest iron ore producer, followed by Quebec..."
Main Minerals and Metals Produced in Canada

As you can see from the quote above the rest of the watershed is also exceedingly rich in iron.

Another look at the Grand Banks seems in order. On the left: the Saint Laurence empties in the Atlantic exactly where the richest fishing was situated in the past . Adding a healthy does of iron to these two nutrient rich ocean currents appears just the thing for intense aquaculture. What would be the extent of the Saint Laurence's impact?
Well, if this river acts like the Amazon then its influence would be widespread.
Now, when we speak of water density the Saint Laurence will be harder to model. Normally the importance of iron is well known but difficult to study because of its complicated biogeochemical cycling .Why would the Saint Laurence be even harder? Because for one thing, the extremes of climate (the waters will often be frozen) and for another water itself has some very odd properties. Among these anomalies of water is the fact that water tends to become purer as it freezes. This would mean the iron would then be concentrated in the water that remained liquid. Moreover, at 4 C water becomes less dense both when chilled or heated. Plotting all this seems quite complicated. Remember that the difference in density

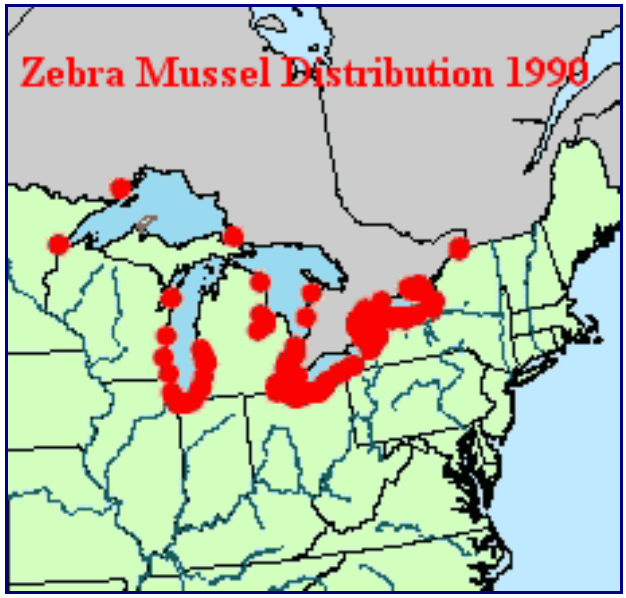


A map of the Grand Banks showing the Labrador and Gulf Currents

is one of the reasons that freshwater from the Amazon did not mix well with the salt water of the South Atlantic Float or sink, figuring out where the iron would spread or mix might tax some of the best computer simulations. Yes, we have a nice source of iron in the Great Lakes and a pathway in the Saint Laurent. Why and how would that have altered?

Zebra Mussels an alien invasion

The United States and Canada have received many exotic and invasive plants and animals over the years. One of the most significant is the Zebra Mussel. There are many examples of how these mollusks have caused ecological change and economic damage. Prolific Zebra Mussel colonies plugging water intake pipes or covering crayfish from claw to tail are some of the more famous examples of these pests.
First detected in the Great Lakes in 1986, with no nature predator the Zebra Mussels (*Dreissena polymorpha*) expansion throughout waterways of North America is nothing short of spectacular. Not only did they have no native predator, but these molusks had an interesting way of discouraging would be predators. Zebra mussels, like many other animals: the monarch butterfly, poison dart frogs, etc are not poisonous per se. However, they tend to stock poisons and toxins in their bodies to discourage preditation. Zebra mussels can accumulate thousands of times the levels of ambient toxins into their own tissues. In addition, Zebra Mussels are voracious filter-feeding organisms. In rivers and streams they have literally starved to death many of the native animals. To understand the great changes these tiny mollusks have made it is necessary to know the prior conditions. In the early 1980s the Great Lakes suffered from a great deal of pollution often in the form of heavy metals like mercury, cadmium



As early as 1990 Zebra Mussels had transformed Lake Erie and Ontario. If you click on the image you will go to an interactive map. At about the same time on the Grand Banks, fishing stocks were plummeting.

or lead. Algae blooms were common.

Many lakeside communities began to consider just how much purification was needed to continue to use lake water for drinking. After the invasion of the Zebra Mussels most of these projects were scrapped. The unrestricted growth of the Zebra Mussels had dramatically reduced pollution levels of heavy metals. Pollution has been transfered from the water column and deposited in sediments through feces and pseudo- feces or amassed in the bodies of the Zebra Mussels themselves. The Great Lakes continue to receive new influxes of heavy metals, PBCs, pesticides and the like. However, their levels are significantly lower than before the introduction of the Zebra mussels. Changes in water clarity give us a yardstick to measure the impact of this invasive species. Let's take just one example. Before the zebra mussels came to Lake Erie, water quality was diminishing. Because of all the algae and particles, sunlight penetrated only thirty to sixty centimeters below the surface. Bottom dwelling plants were hard pressed to survive and never far from the shoreline. After the invasion, water transparency jumped to two or three meters.

Zebra Mussels can accumulate pollutants in their tissues 300,000 times the local environment.
They often collect on any solid surface from coke cans to coolant pipes for nuclear reactors.

There was an explosion of bottom dwelling aquatic plant life well out into lake. These plants provided new nursing grounds for many species of fish. Be not confused by these beneficial effects. The Zebra mussels are the underwater version of Australia's rabbit population. How much plankton in the Great Lakes disappeared? (BTW: There are methods for estimating plankton density via their absorption of light.) . Suffice to say that just for the case of Lake Erie there must have been the removal of a huge quantity of biomass. What would be the amplitude of the the ecological effect? Remember, the Great Lakes are really freshwater seas. Freshwater algae remove carbon dioxide from the atmosphere. Their disappearance in the Great Lakes alone contributes to Global warming in some manner. If Grand Banks plankton was also affected then the amplitude of the loss of this carbon fixing biomass may be truely astounding.

Zebra Mussels are considered one of the greatest nuisance species in North America. As we have seen, they have extensively changed the Great Lakes region. Could their economic impact have been grossly underestimated? Now we must enter the realm of supposition. It is not difficult to imagine if the Zebra Mussels continue to limit mercury levels in Lake Erie or Ontario then they would do the same for iron levels. Iron in large doses can be quite toxic. Fe might be included in the Zebra Mussels defense strategy. If this were the case, then iron levels would be drastically lower. What is nice about this cause is the times seems to be just right. No need for a decade or a century between cause and effect. As Zebra Mussels expanded throughout North America Atlantic fishing decreased. Understanding why this may have been ignored is realitively easy: the iron transfer in the Great Lakes has not been well studied. Determining how iron migrates throughout the Great Lakes/Laurentine watershed now and especially in the past is daunting. In the abstract of Consideration of the bioavailability of iron in the North American Great Lakes
R. Michael et et al Journal of Great Lakes Research 31 (S2): 180-194 2005
is found: *"Despite its importance, the biogeochemistry of iron in the water column of lacustrine systems remains poorly characterized. "*. Therefore as late as 2005, iron transfer and availability in the Great Lakes is both cutting edge and undiscovered territory. Add to that the need to understand how an iron source hundreds even thousand of kilometers away can effect a marine habitat is very challenging and not run of the mill. For example, soluble iron in the Saint Laurence is only one vector. Lake and river plankton may be another rich source of iron. Plankton like the Zebra Mussel tend to accumulate pollutants in their cell tissue. Just a few years ago, the mantra for pollution was: " *The solution to pollution is dilution*." But this ignores one of life's defining characteristics "anti entropy". For example: Let's examine high mercury pollution levels in ocean top feeders like the tuna. The source of their mercury lies at the very bottom of the food chain: plankton. Plankton accumulate mercury in their bodies that are many times greater than in environment in which they live. . They would do the same with Fe an essential micronutrient. (Ironically when you consider how rare Fe is in the oceans, marine plants are traditionally high in

iron content) Hence, plankton, itself may contain extremely high concentrations of iron when immersed in an iron rich environment.
Futhermore, iron transported by plankton would include both intracellular and extracellular Fe (attached to the surface of organisms). This iron might represent a greater source of iron than that just dissolved the water .
Perhaps the whole Grand Banks ecosystem depended on this influx plankton and iron rich water for its very existence.
Given this, what would be the impact of zebra mussels to these proposed iron transport methods?

For both water born and plankton inclosed iron transport, zebra mussels could have reduced this exchange to almost nothing:

1. 1. As suggested earlier, levels of iron in the water may have dropped dramatically with the introduction of these mollusks (as did other metals.)
2. The amount of phytoplankton has been severely reduced and the algae that remain should be no longer living in an iron rich environment thus depleting there intrinsic iron content.

As the zebra mussels continue to spread into small streams and rivers further from the Great Lakes, Saint Laurnce river, and the Canadian and American Eastern seaboard their devastating economic effect on marine fishing should increase.

Conclusions and Future Work
This article is a long chain of hypotheses. As a balancing act it does quite well. The main questions now are *Could a lack of iron in the Grand Banks really be prolonging the depletion of its fisheries?* and *Did the invasion of the Zebra Mussels remove the iron from the Great Lakes and Saint Laurence River watershed? Are the two connected?* Is there is some way of verifying or testing these two hypotheses? It seems that, at the very least, taking river and ocean sediment core samples and then identifying any changes over time in iron distribution is called for. However, because of iron's essential use in biological systems and extensive biogeological recycling, finding meaningful data may not be forthcoming. Some technique to measure the loss of carbon fixing plankton in the Grand Banks and estimate the resultant effect on our planet is also necessary. Examining closer life's role in iron distribution throughout the Great Lakes, Saint Laurent, and Grand Banks is also in order. A systems analysis is required and would employ many researchers. What a time to be a marine biologist.
Further Work
In evolutionary terms, marine ecosystems would have to be very frugal with iron and iron transfer in order to maximize life. This is a corollary of the Gaia hypothesis. There are examples of entire ecosystems optimizing some factor to maximize life. If we return to the Amazon rainforest, surprisingly, the growth is more rapid in the dry season. This would only be true if collectively the trees with deep tap roots are bringing up water for the whole system. Maybe the same sort of interspecies collaboration/optimization is going on in the Great Lakes & Grand Banks interplay with iron. Understanding these continent wide processes will be an electrifying study.

If premses of this paper prove to be true, there will be the knotty problem of rectifying the mineral deficiency. Research is ongoing on the best way to deal with *Dreissena polymorpha.* As with most invasive species there seems no effective treament and it is too late for prevention. Can we repair ecological catastophes (Zebra Mussels & the colapse of the Grand Banks) via artificial means?
On one hand we would be tinkering with the planet on a grand scale and on the other we would be trying to imitate an existing (abet earlier) natural iron fertilization scheme . With concerns for Global Warming at an all time high, conceivably it is right moment to examine as well a less anthrocentric perspective of the causes of this Global Warming. It is possible that the distruction of the ocean's equivilent of a major rainforst is a contributor to rising planetary temperatures. It may be possible to soften these effects with the controlled introduction of iron in the waterways of Canada and the US.
But this hypothesis has to be verified first before we consider salting snow covered roads with iron salts.
As you may have noticed this article reads more like a mystery story. You have all the pieces of the puzzle I leave it up to you to decide if they fit together.
Christopher YUKNA

Teachers
You may want to take your students on a webquest on this topic. Why not let them formulate their own conclusions? Learning how to navigate efficently through web and understanding critical thinking are needed skills to develop:
Simply, print one of more of the Grand Banks Zebra Mussels webquest Page
http://yukna.free.fr/science/zebramussels/webquest.html
cut out the squares and give them to groups of your students. Give them at least a half an hour in class or as homework
to prepare a short presentation of what they researched. This should produce lively discussions
They may want to use the CyberNautilus to search the web.
http://yukna.free.fr/science/search/cybernautilus/cybernautilus.php
which uses *Scirus, Google Scholar, as well as other sources like Google and Wikipedia.*

Citations and or further reading:

Overfishing
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Acknowledgements:
Much thanks to My four Musketeers: Gustavo DeSilva, Bernard Guy, Didier Graillot and Francois Valdivieso for listening to me and helping clarify my ideas.
Jacques Bourgois for his insights in natural mining pollution.
and especially for my perfect English editor Liliane Bois Simon